

ERIC Document Resume		See Instruction Sheet		DATE OF RESUME	7/15/65	DATE RECEIVED
A. PUBLICATION DATA						
1. ERIC NUMBER ED000362		2. ORIGINATOR CONTROL NO(S) 7096		3. IDENTIFICATION NO. N.A.		DO NOT WRITE IN SPACE BELOW
4. AUTHOR(S): Throop, Joseph F., Assini, Lewis T., and Boguslavsky, George W.						MICROFILM COPY AVAILABLE YES ☒ NO ☐
5. TITLE OF DOCUMENT ABSTRACTED: The Effectiveness of Laboratory Instruction in Strength of Materials by Closed Circuit Television						COPYRIGHT GRANTED YES ☐ NO ☒
6. PUBLICATION TITLE: N.A.						COPYRIGHT RELEASE FILED YES ☐ NO ☐
7. EDITOR(S): N.A.				8. PLACE OF ORIGIN ORG. FPI ST. Troy, NY CITY, STATE		TYPE OF REPORT PROPOSAL ☐ IN-PROGRESS ☐ FINAL ☒ FOLLOW-UP ☐
9. PUBLISHER OR SOURCE Rensselaer Polytechnic Institute				TELE. EXT. INST/LOC CODE		
10. VOL. N.A.	11. PAGES N.A.	12. MO./YR. 59	13. TOTAL PP. 41	14. SUBJECT AREA		OTHER ERIC REFERENCES:
B. INDEXING DATA						ERIC SATELLITE CODE
15. TYPE OF ENDEAVOR experimental study						
16. INDEXING TERMS (6-12)						
experimental studies G-23		educational television G-11		students Y-15		
teaching methods Y-25		science Y-04		opinions P-03		
laboratories O-00		effectiveness G-12		finance G-31		
17. ABSTRACT (MAX. 250 WORDS)						

Study on the effectiveness of televised instruction as compared with conventional laboratory instruction of 12 materials laboratory experiments. Describes instructional techniques employed, measures of attainment, analysis of student opinion, comparisons of costs, conclusions, and recommendations.

ERIC No.	16. SOURCE OF ABSTRACT		
	C. FUNDING DATA		
	19. SUPPORTING ORGANIZATION	20. DIVISION OR DEPT.	21. CONTRACT NO.
		22. TOTAL COST OF PROJECT	PROJECT NO.
	23. DURATION OR PROJECT	U.S. Department of Health, Education, and Welfare Office of Education	

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

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\\ THE EFFECTIVENESS OF
LABORATORY INSTRUCTION
IN
STRENGTH OF MATERIALS
BY
CLOSED CIRCUIT
TELEVISION //

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NOV. 8, 1958



Rensselaer

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ED 000362

THE EFFECTIVENESS OF LABORATORY INSTRUCTION IN
STRENGTH OF MATERIALS BY CLOSED-CIRCUIT TELEVISION

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The Department of Mechanics
assisted by grants from
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and
The Educational Television and Radio Center,
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November 8, 1958

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THE EFFECTIVENESS OF LABORATORY INSTRUCTION IN
STRENGTH OF MATERIALS BY CLOSED-CIRCUIT TELEVISION

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ABSTRACT

The quiz scores, term-paper grades, examination marks and course grades, along with a questionnaire of student opinion, are analyzed to evaluate the effectiveness of televised instruction as compared with conventional laboratory instruction of twelve Materials Laboratory experiments. The attainment of 234 engineering students instructed over closed-circuit television by senior faculty members is compared with the attainment of 199 equally able engineering students instructed in the same term in the conventional manner by part-time laboratory instructors.

The grades show no significant difference in the attainment of the two groups. Analysis of various categories of quiz questions and questionnaire results suggests improvements in the television presentation which may make it more effective for large enrollments than the conventional instruction. Given comparable populations, the television method of instruction is just as effective in achieving the educational objectives of the course as the conventional laboratory procedure. The television method is not economically justifiable for this course unless the number of students approaches 400 in each term.

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Introduction

The Materials Laboratory Course 17.60 has traditionally been taught at Rensselaer Polytechnic Institute to small laboratory sections with an instructor supervising each section throughout the class period. Long ago, five students in a section was considered reasonable, but the number has gradually been increased until ten, and sometimes twelve or thirteen, students work as a section. At the same time, the class sizes have increased so that many sections must be scheduled, with two or four sections in the laboratory every period from early morning till late afternoon throughout the week. This number of sections requires the use of graduate students as part-time instructors, who require training and supervision by full-time faculty members. This training is a continual process because of the staff turnover attendant upon the completion of their graduate studies. The replacement of from ten to twelve part-time instructors each year has become necessary.

Although an increase in the laboratory space and the number of experiment sites may reduce the number of students per laboratory section, it increases the number of instructors needed and the attendant problems of staff turnover. It also involves large capital expenditure since materials-testing equipment such as is used in research and industrial laboratories is inherently costly.

Amphitheater-type demonstrations, motion pictures, and closed-circuit television appeared to be possible ways of increasing the effectiveness and productivity of the experienced full-time faculty members by enabling them to give instruction directly to larger numbers of students. With enrollments steadily increasing, it became desirable to investigate the possibilities of using these for

laboratory instruction.

Closed-circuit television was selected for investigation on the assumption that live television might depart less from the actual laboratory situation and give the student more of a sense of spontaneity and participation in the experiments than would films. The data taken by each group of students would be new and real data from which they could compute their own experimental results. Moreover, the experiments could be changed readily from term to term. The use of a two-way sound system, permitting immediate questions from the class and answers from the laboratory, was expected to enhance further the sense of participation.

The objective of the course is to impart an understanding of the mechanical behavior of engineering materials, and structural elements, rather than to train the student in the techniques of materials testing. The argument of this report is that actual contact with the machines and equipment is not necessary for achieving this objective.

Several advantages and disadvantages of televised laboratory instruction were anticipated. Every student would see the performance of the experiment from the same vantage point, but he would not handle the apparatus, make his own mistakes in the laboratory, and do the experiment himself. The class would view a carefully planned presentation of each experiment conducted by professors of considerable experience in the subject; however, the students would not have a part in the planning and preparation for the experiment. The best and newest of the laboratory apparatus could be used without the necessity of duplication of costly laboratory facilities, but the expense of television equipment, its installation and maintenance would be incurred. No expansion of the laboratory space would be required to meet

increasing enrollments, but additional classroom space suitable for television reception and computation work would be required. Additional and supplementary information could be brought into the course readily by means of charts, slides, and films, but the preparations and rehearsal for each experiment would require extra work on the part of the instructional staff.

It was felt that if the television instruction could be done effectively the advantages would outweigh the disadvantages. Consequently, a study was started in February 1957 of the possibilities of televised instruction for the Materials Laboratory course. Such instruction was given to 234 members of the class during the spring term of 1958. In the same term, a control group of 199 students received instruction by the conventional laboratory method. Comparison of the results between the two groups may be of interest in connection with other science and engineering courses involving demonstrations and laboratory experiments. The study was initiated in the Department of Mechanics with the assistance and support of Rensselaer's Project Reward. Funds for partial support of the project were granted from the General Electric Educational and Charitable Fund, and a grant-in-aid towards the cost of evaluating the effectiveness of the instruction was made by the Educational Television and Radio Center, Ann Arbor, Michigan.

Preparation for Television

In this study particular attention was given to determining the necessary television, lighting and sound equipment, and to developing production methods suitable for presenting the subject matter of the Materials Laboratory course. Considerable time was devoted to the matter of obtaining close-up views of sufficient quality that the viewer would be able to make his own examination of fractured specimens, perceive the details of construction of apparatus, take his own instrument readings, and read his own values from autographic data records directly from the image on the television screen.

During 1957 the television equipment, consisting of two industrial camera chains and five 21-inch screen video monitors, was acquired. Lighting, color separation, sequence of camera shots, and scripts for the twelve experiments were developed. A technique for producing split-image views with the two cameras was devised. Modifications were made in some of the laboratory machines and instruments in order to make them more readable on the television screen. A movable lighting system employing adjustable supports was adopted, and the positions of lights and equipment were charted for each of the experiments. The laboratory became essentially a television studio, with drawn shades to control external light; with a grid marked on the floor to aid in relocating cameras, lights, and equipment; and with the testing machines painted in contrasting shades of green, gray and yellow to provide gray-scale separation for ease in identifying their parts. All of the television equipment was mounted on casters so that it could be moved readily from one experiment site to another. Portable backdrops made of plywood panels could be moved from site to site to provide uncluttered backgrounds for the cameras.

A turntable, also on casters, was devised with special mountings for holding fractured specimens, instruments, and charts or graphs. This permitted displays to be quickly mounted and rotated into view of a prefocused camera so as to provide the best positioning and lighting. Display charts, schematic diagrams and data tables were prepared on gray cardboard for viewing by the cameras. These were made relatively permanent to permit their re-use in subsequent terms. In addition, instruction sheets, data sheets, and mimeographed reproductions of typical autographic data records were prepared to hand out to the students in both the television group and the control group.

The television script, recorded in picture-story form, showed the object to be viewed, the camera location, and the lens to be used for each camera shot in the sequence. Alongside each picture was indicated briefly what the professor would do and what he would say while the picture was being viewed. Split-image shots were shown in the same manner, with appropriate instructions for each camera. During the preparation for each experiment a written record was kept to make it possible to set up the equipment again at any time for rehearsal and presentation to an audience.

Technique of Instruction

Each Friday afternoon the site of the experiment for the next week was prepared for televising, and the sequence of camera shots was tried to be sure that everything was in readiness. On Monday morning the television crew of professor, program director, two cameramen and the technical advisor rehearsed the performance of the experiment from 9 a. m. until noon. The professor was Joseph F. Throop and the program director was Lewis T. Assini, both Associate Professors of the Department of Mechanics. The cameramen were Iradj G. Tadjbakhsh and Felix von Gemmingen with George H. Hilton as alternate cameraman, all graduate students in Mechanics. The technical advisor was William L. Millard, Assistant Professor and audio-visual specialist on the staff of Project Reward.

The television classes were conducted in 2-hour periods starting at 1 p. m. and 4 p. m. on Monday and at 8 a. m., 1 p. m., and 4 p. m. on Tuesday. After the last class on Tuesday, the television apparatus was removed from the experiment site. The conventional laboratory classes then met in 2-hour periods starting at 8 a. m. on Wednesday and going through the remainder of the week until Friday noon. During each of the conventional laboratory periods, there were two sections of 10 to 12 students in the laboratory, each performing its own experiment under the supervision of an instructor. These instructors this term were graduate students with more than the usual amount of teaching experience, several having been with the Department over two years.

The television classes were conducted with 40 to 50 students in a classroom adjacent to the laboratory. The students occupied movable tablet-arm chairs. At the beginning of the period the professor gave a 15- to 20-minute

blackboard discussion of the day's experiment, reviewing briefly the theoretical relationships involved, indicating the nature of the data to be taken, outlining the method of analysis to be used with the data, and suggesting some engineering applications that might be made of the experimental observations and results.

After this introduction, the professor left the class, went to the laboratory, and proceeded to conduct the experiment. The class watched the performance of the experiment on the screens of four 21-inch video monitors, two located at the front of the room at either side of the blackboard and the other two located at the sides of the room midway from front to back. The centers of the screens were about six feet from the floor, and the monitors were tilted slightly forward to provide the best angle of sight from the chairs. The students in the rear of the room could face the monitors at the sides of the room for best vision. The window shades of the room were drawn to prevent glare, but a bank of fluorescent lights directly above the monitors was left on to provide enough light for notetaking. Underneath each monitor was a high-fidelity speaker over which the instructions and commentary of the professor in the laboratory could be heard. Above the blackboard at the front of the room was a microphone over which members of the class could ask questions. It was sensitive enough to pick up questions from the rear seats if they were spoken clearly. The class was left unattended except for this live microphone which was connected to a speaker at the experiment site and to an earphone which the professor wore. Both sound circuits were open during the televising, with their volumes adjusted to prevent feedback. The class and the staff could hear each other at all times.

It was found best for the professor to wear an ear-phone so that he could hear questions above the noises of the testing machine at his side. The rest of the crew could hear the questions over the speaker located on the control console adjacent to the experiment site. When a question was indicated by voice from the classroom, the professor switched off his chest microphone, thereby automatically boosting the volume from the questioner and preventing feedback. Having heard the question, he switched his microphone on again and answered the question. A conversation with a student in the class could be carried on readily in this manner, with all parties hearing both sides of the discussion.

The television instruction was started with a pre-action televising period in which the professor explained the function and operation of the experimental apparatus, partly with the aid of schematic diagrams and partly with the apparatus itself. The initial dimensions of specimens were measured and the specimens were prepared for testing. Then the professor faced the camera and asked the class for questions about the experimental setup. Although the camera shots ordinarily followed a planned sequence, during the question period the professor selected whichever camera seemed best for providing pictures with which to illustrate his answers.

He then proceeded with the action-televising period. In this period the two cameras took turns in following his movements and in providing close-up views of load scales, strain indicators and recording devices used in the experiment. The program director guided the cameramen in accordance with the picture-story script, supervising the sequence and quality of picture transmission and directing their camera movements and settings. He used a microphone connected to earphones worn by the cameramen. The professor followed

the script from a copy held on a clip-board. He also recorded data for future reference on a data sheet on the same clip-board, making its use seem part of the experimental procedure.

The split-image technique was used to advantage frequently during the experiments for observing two events that occurred simultaneously. For example, in a tensile test one camera watched the indicator of an extensometer on the specimen while the other camera watched the load indicator of the testing machine. With both views showing on a split-screen image the student could take his own readings of load versus elongation suitable for plotting a graph. Side-by-side pictures of schematic diagrams and actual mechanism were also produced effectively.

During the action phase of television, the timing of the camera shots was governed principally by the behavior of the test specimens which was subject to the professor's control of the testing machines. The picture sequence was generally continuous and in accordance with the script. However, if an interruption occurred, either by a question from the class or by an accident such as the failure of a recording pen to function properly, the program director merely kept his cameras on the professor and the most pertinent part of the experiment while the professor answered the question or cleared the fouled pen. The action then resumed according to the planned sequence of shots. When the test of a specimen or group of specimens was completed, the professor again asked for questions and used either or both cameras to aid in answering them.

When the performance of the experiment was completed, a period of post-action televising was generally used. The appearance of the fractured specimens was viewed, their final dimensions were measured, the autographic data records were

examined, and a completed data table was displayed. Supplementary information pertinent to the experiment was frequently shown, and the professor gave a brief blackboard explanation over the television system, showing the manner in which the data should be analyzed and the results computed. It was found that this discussion was more effective when presented over television at the end of the experiment than when given in the classroom previous to the televising. Finally, the professor finished with a question period. The experiments were planned so that the televising took approximately one hour, and generally the script called for about 50 different camera shots.

After the last question was answered, the television and sound equipment was turned down and the staff returned to the classroom for the remainder of the two-hour period to assist with the computations and interpretation of results. The specimens that had been tested were brought along to provide the students a firsthand inspection.

The professor, the program director, and the two cameramen each took charge of one quarter of the class, giving personal guidance to the students in a portion of the room. The 10 to 13 students in each man's portion became his section, responsible to him for their records and grade in the course. He kept their attendance records, read their term papers, and provided them personal consultation in his office hours.

Measures of Attainment

Student learning was measured by means of objective-type quizzes, a term-paper grade, and an objective-type common examination. The quizzes were used to measure the effectiveness of communication and were not used in computing the course grades. The course grades were based 50% on the term-paper grade and 50% on the examination mark.

The objective quizzes were given every two weeks throughout the term, covering the experiments given in the two preceding weeks. The first eight quizzes consisted of one question on the testing machines, one question on instrumentation, two questions on specimen behavior, and one question on theoretical relationships. These pertained to the eight experiments dealing with the testing of material specimens for strength, ductility, mode of fracture, and other mechanical properties. The other four quizzes consisted of two questions on instrumentation, one question on specimen behavior, and two questions on theoretical relationships. These dealt with the experiments involving strain measurements and analysis of stresses and deflections of simple structural elements. Each student thus answered eight questions on testing machines, sixteen questions on instrumentation, twenty questions on specimen behavior, and sixteen questions on theoretical relationships. A system of reusing questions in different combinations for different classes was devised to insure uniform quizzing of both the television group and the control group.

The first six sets of quizzes were prepared by the two associate professors of the television staff. Since they had also prepared the scripts for the television instruction, a certain bias towards the television group was believed unavoidable, so the last six quizzes were prepared by the instructors of the conventional laboratory sections. These

were expected to be somewhat biased toward the control group. In scoring the quizzes a double penalty was given for wrong answers, single penalty given for unanswered questions, and full credit given for correct answers. Assuming an equal bias in each group of quizzes, an analysis of the number of wrong answers, unanswered questions, and correct answers serves as a means of evaluating the effectiveness of communication of each of the categories of information by television as compared to conventional instruction of students at the experiment site.

The term-paper grade reflects the faculty member's subjective opinion of the student's understanding of the course, based on a 10- to 15-page composition about the behavior of engineering materials; the data, graphs, and computations submitted by the student; and whatever personal contact he had with the student. Although the television staff had less personal contact with the students than the instructors of the conventional sections did, an attempt was made at frequent staff conferences to maintain a uniform basis among the whole staff for assigning this grade.

The final examination consisted of 30 multiple-choice questions and one problem involving computations, analysis, and interpretation of a set of laboratory data. It was prepared jointly and graded jointly by the whole staff in order to avoid any bias toward either the television group or the control group.

Statistical Analysis of Attainment

Assignment of a student to a section was determined primarily by the period available in the student's academic schedule. This method of assignment, though not strictly random, was expected to yield comparable populations in the TV and the control groups. The populations would be judged comparable if they satisfied the following two criteria:

1. Students from each major department should be divided between TV and control sections in proportions which do not deviate significantly from the overall proportion of 234:199.
2. The accumulated grade-point averages in the two groups should have means and variances which do not differ significantly.

In accordance with frequently used statistical convention, a significant deviation was arbitrarily defined as a deviation which would occur 5 or fewer times in 100, if chance alone were operating.

The two populations were examined for satisfaction of the first criterion on the basis of the distribution shown in Table 1.

Table 1

Distribution of students from the
several major departments between
TV and control groups

	EE	ME	AE	CE	Mgt.	Misc.*	Total
TV	95	41	39	23	21	15	234
Control	74	39	37	23	18	8	199
Total	169	80	76	46	39	23	433

*Misc. includes Architects, Metall. Engrs., Chem. Engrs.,
and students with undesignated major.

The given figures were subjected to chi-square analysis, which yielded $\chi^2 = 2.2586$. According to the chi-square tables, this value indicates that the distribution of students between TV and control groups is well within chance expectation. The first criterion for comparability of the two populations may, therefore, be regarded as satisfied.

Examination of the two populations for satisfaction of the second criterion was based on accumulated grade-point averages of 225 students in the TV group and 191 students in the control group. (The figures were not available for 9 TV students and 8 control students). All the averages were calculated at the end of the first term of 1957-58. The means and standard deviations of the accumulated grade-point distributions in the TV and control populations are shown in Table 2.

Table 2

The means and standard deviations of accumulated grade-point averages

	Mean $\pm \sigma_M$	SD $\pm \sigma_{SD}$
TV	2.40 $\pm$.04	.60 $\pm$.03
Control	2.35 $\pm$.04	.58 $\pm$.03

Differences between the means and between the standard deviations were tested for significance by the method of Critical Ratio. Neither difference was found to be significant. Hence, the second criterion for comparability may also be regarded as satisfied.

When comparable populations are subjected to different treatments, the differential effect, if any, should appear as a significant difference between mean attainment scores on a common measuring instrument. As described earlier, four common measuring instruments were used to compare the attainments of the TV and the control groups: 12 quizzes, a term paper, the final examination, and the final grade. The mean scores of the two populations on these four instruments are shown in Table 3.

Table 3
Mean Scores ($\pm\sigma_M$) of TV and control populations
on four measuring instruments

	12 Quizzes	Term Paper	Final Exam	Final Grade
TV	55.7 $\pm$.8	3.17 $\pm$.08	77.6 $\pm$.7	2.87 $\pm$.05
Control	56.8 $\pm$ 1.0	3.20 $\pm$.05	77.0 $\pm$.7	2.80 $\pm$.06

The Critical Ratio test shows that the differences between the corresponding means on all four instruments are not significant. Hence, one may infer that the two methods of instruction are equally effective in achieving the objectives of the course.

It should be noted that the final grade is a composite measure, based on the term paper and the final examination, thus involving both the subjective and the objective evaluation. Therefore, as a measure of attainment it is probably the most comparable one with evaluating procedures used in other courses. On the basis of this assumption, the final grade was used as an index of the extent to which the two methods of instruction exploited the student's capacity. The accumulated grade-point average was used as index of the latter. Comparisons of the two indices are shown in Table 4.

Table 4
Mean values ($\pm \sigma_M$) of accumulated grade-point
averages and of the final grades

	Acc. G.P.A.	Final Grade	Increment	Δ in %
TV	$2.40 \pm .04$	$2.87 \pm .05$	+ 0.47	+ 19.6
Control	$2.35 \pm .04$	$2.80 \pm .06$	+ 0.45	+ 19.1

It is apparent that students in both populations performed in the course significantly better than one might expect from previously accumulated averages. The improvement may be attributed to one or more factors, such as relative ease of subject matter, generosity in grading, or excellence of instruction. Isolation of the main determinant cannot be accomplished with the present data, nor is such isolation pertinent to this investigation. The relevant fact is that the two increments are practically identical. This evidence lends added support to the inference that the two methods of instruction were equally effective.

Analyses of data in terms of group averages may not reveal the more subtle effects of different treatments. Thus, the figures of Table 4 lead one to expect that the group averages will improve to about the same extent under both methods of teaching; they do not indicate, however, the certainty with which this conclusion applies to an individual student, enrolled in a particular section and exposed to one of the two methods of instruction.

To obtain this information, correlations between accumulated grade-point averages and final grades of individual students were calculated separately for each section.

Because the final grades, being letter grades, provide a limited number of categories and are not necessarily distributed normally, the coefficients of correlation were calculated by the rank-order method. When the number of categories in one variable is limited, the method suffers from having the same rank assigned to a relatively large segment of the population. Hence the ρ -coefficients listed in Table 5 and plotted in Figure 1 should be regarded only in relation to each other rather than absolute predictive indices.

Table 5

Coefficients of correlation (ρ) between accumulated grade-point averages and final grades in the course. (See Figure 1)

TV					
	Monday		Tuesday		
Time	1-3	4-6	8-10	1-3	4-6
ρ	.46	.66	.60	.39	.35

CONTROL										
	Wednesday			Thursday				Friday		
Time	8-10	10-12	2-4	8-10	10-12	12-2	2-4	8-10	10-12	12-2
ρ	.70	.78	.58	.09	.65	.42	.58	.28	.38	.34

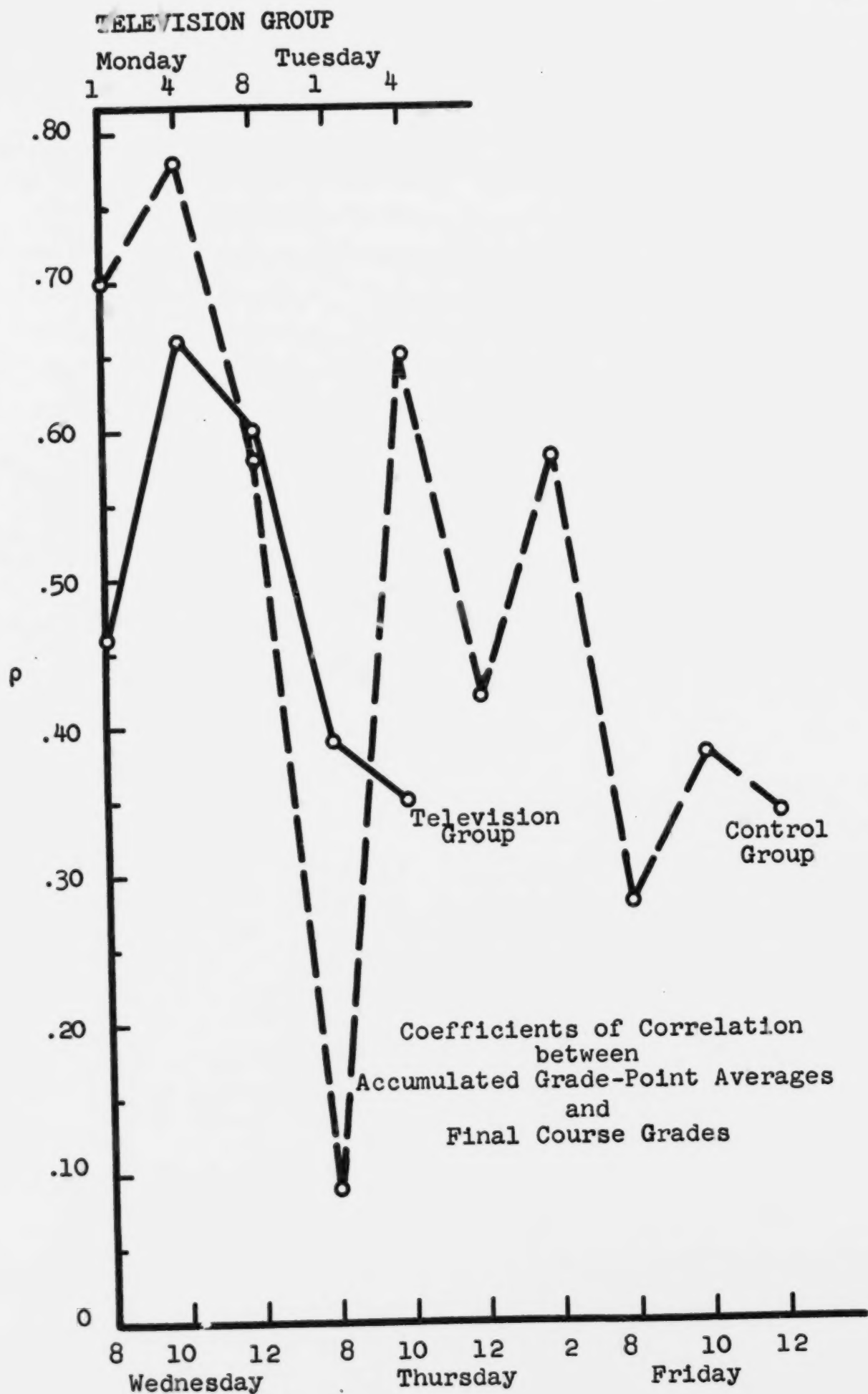


Figure 1

If it is assumed that the coefficients of correlation reflect effectiveness of communication, a scrutiny of the data plotted in Figure 1 warrants the following inferences:

1. Communication is maximally effective during second presentation of the instructional material under both methods of teaching.

2. With subsequent presentations of the same instructional material, the effectiveness of communication tends to decrease under both methods of teaching.

3. The effectiveness of communication varies less under TV method of instruction than in the conventional laboratory procedure.

Another possibility not revealed in the over-all analysis is that the effectiveness of a particular method of instruction may be a function of the student's major field of study. This possibility was investigated by comparing the mean scores on the final examination for each major degree department separately. The final examination was selected as the criterion because it combined comprehensiveness with objectivity, and because it was sufficiently removed in time from the instructional periods to serve as a measure of long-term retention. The data are listed in Table 6.

Table 6

Mean scores on final examination

	EE	ME	AE	CE	Mgt. E.	Misc.
TV	79.4 $\pm$ 1.1	78.9 $\pm$ 1.5	77.7 $\pm$ 1.7	72.8 $\pm$ 2.3	75.7 $\pm$ 2.5	71.9 $\pm$ 2.8
Control	76.9 $\pm$ 1.2	80.7 $\pm$ 1.3	78.5 $\pm$ 1.0	75.0 $\pm$ 2.5	72.1 $\pm$ 2.9	70.5 $\pm$ 3.4

Differences between the means of each major degree department were tested for significance by a statistical test for small samples ("Student's" t-test). None was found to be significant. Hence the hypothesis that effectiveness of a method of instruction depends on the student's major field must be rejected.

An examination of Table 6 shows that the mean scores of E.E.'s, M.E.'s, and A.E.'s are consistently higher than those of C.E.'s, Mgt.E.'s and Miscellaneous. Two likely (but not mutually exclusive) explanations may be suggested for the phenomenon: (1) both instructional procedures favor differentially the various major degree departments; and (2) the various major degree departments are represented by students of differential capacities.

In a search for the more plausible of the two explanations, mean values of the accumulated grade-point averages were calculated separately for each major degree sub-group. These are shown in Table 7.

Table 7

Mean values of accumulated grade-point averages

	EE	ME	AE	CE	Mgt. E.	Misc.
TV	2.47 $\pm$.02	2.45 $\pm$.03	2.44 $\pm$.03	2.11 $\pm$.04	2.33 $\pm$.03	2.17 $\pm$.03
Control	2.33 $\pm$.02	2.40 $\pm$.03	2.49 $\pm$.03	2.21 $\pm$.04	2.26 $\pm$.05	2.20 $\pm$.06

The "Student's" t-test shows that differences between TV and control means, within 5 of the 6 major degree groups, do not differ significantly. The only discrepancy which cannot be attributed to chance occurs between the means of electrical

engineers. There is no immediate obvious explanation for the difference. Fortunately, the discrepancy is not of sufficient magnitude to impair the over-all comparability of the two populations.

From the data of Tables 6 and 7, rank-order coefficients of correlation were calculated for the TV and the control groups. Each major degree sub-group served as a unit of population, with the mean grade-point average and the mean final examination score being the two measures. The two coefficients are: for the TV group, $\rho = .94$; for the control group, $\rho = .89$. The high numerical values of these coefficients suggest that the second explanation is more plausible; i.e., differences between mean examination scores of various major departments are due to differences in the average academic capacities of their students.

An important question in the development of a teaching method is whether the method is uniformly effective with the several topics which constitute the course material. The question is pertinent to the present study inasmuch as the course in Materials Laboratory strives to impart to the student four types of sophistication: reasonable familiarity with machinery, accurate identification and reading of instruments, correct description of specimen behavior, and adequate theoretical formulation of the process. Since these four abilities were measured by the quizzes, it is possible to compare how effectively the two methods of teaching communicated each of these features to the students.

The data for the analysis were taken from 2657 quiz papers of the TV group and 2160 quiz papers of the control group. Theoretically, if every registered student had taken all 12 quizzes, there should have been 2808 and 2388 papers,

respectively. The discrepancies are due to "drop-outs" as well as to "make-up" papers not yet placed in the files.

Since each quiz paper contained 5 items, a population of 13285 items was available for the TV group and 10800 items for the control group. The items were divided into 4 categories corresponding to the 4 objectives of the course; and, within each category, record was made of the number of items answered correctly, left unanswered, and answered incorrectly. The results appear in Table 8.

Table 8

Distribution of quiz items by categories
and types of response

TV	Machines	Instruments	Behavior	Theory	Total
Correct	1232	2656	3348	2515	9751
Unanswered	96	203	215	216	730
Incorrect	464	659	894	787	2804
Total	1792	3518	4457	3518	13285

CONTROL	Machines	Instruments	Behavior	Theory	Total
Correct	1081	2171	2718	2122	8092
Unanswered	48	98	125	117	388
Incorrect	311	616	747	646	2320
Total	1440	2885	3590	2885	10800

For the purpose of rapid comparison, the figures of Table 8 are translated in Table 9 into percentages of the total number of items within the category.

Table 9

Distribution, in %, of quiz items by categories and types of response

	Machines		Instruments		Behavior		Theory		Total	
	TV	Conv.	TV	Conv.	TV	Conv.	TV	Conv.	TV	Conv.
Correct	68.7	75.1	75.5	75.3	75.1	75.7	71.5	73.5	73.4	74.9
Unanswered	5.4	3.3	5.8	3.4	4.8	3.5	6.1	4.1	5.5	3.6
Incorrect	25.9	21.6	18.7	21.3	20.1	20.8	22.4	22.4	21.1	21.5
Total	100	100	100	100	100	100	100	100	100	100

A cursory inspection of Table 9 yields two important observations: (1) the TV method appears less uniformly effective with regard to the four topics than the conventional method; and (2) the students in the TV classes tend to leave more questions unanswered than the students in the conventional laboratory classes. Significance of these observations was tested by applying the chi-square method to the data of Table 8.

The first analysis examined the proportional distribution of items according to the 2 x 2 schema shown in Table 10.

Table 10

Schematic representation for χ^2 analysis of correct responses to quiz items

	TV	CONTROL
Correct	N_1	N_2
Unanswered + Incorrect	N_3	N_4

The schema was applied successively to each of the four categories of items. The obtained χ^2 values permit the following conclusions:

1. In the effectiveness of the teaching of instrumentation and specimen behavior, any difference between the two methods may be safely attributed to chance.
2. In the teaching of theory, the conventional method has been somewhat superior to the TV method. The superiority, however, is not of sufficient magnitude to warrant the rejection of the chance hypothesis.
3. In the development of familiarity with machinery, the conventional laboratory method has been more effective than the TV method, beyond chance expectation.

The second χ^2 analysis was done according to the schema shown in Table 11.

Table 11

Schematic representation for χ^2 analysis of unanswered vs. incorrectly answered quiz items.

	TV	CONTROL
Unanswered	n_1	n_2
Incorrect	n_3	n_4

In this test the proportions were found to differ significantly in three of the four categories. The effect is probably due to the somewhat stronger injunction in TV classes against guessing. It appears likely that if an equally strong injunction were made in the control group, the percentage of

unanswered questions in this group would be increased, with a corresponding decrease in the percentages of correct and incorrect answers.

A problem of interest is the extent to which the sampling of student knowledge corresponded to the course content. As described earlier, the first 6 quizzes were prepared by the TV faculty and the last 6 quizzes by the control-group staff. Table 12 shows the mean values for these two phases of testing.

Table 12

Mean scores of TV and control groups on the first 6 and the last 6 quizzes

	First 6 Quizzes	Last 6 Quizzes
TV	57.6 $\pm$ 1.0	52.2 $\pm$ 1.0
CONTROL	55.1 $\pm$ 1.2	59.1 $\pm$ 1.2

As has been suspected, the values of Table 12 indicate a bias in the preparation of quizzes in favor of members of own group. The difference between the means on the first 6 quizzes borders on the level of significance ($p = .056$), and may be assumed to represent the presence of some bias, though the factor of chance cannot be ruled out with certainty. In the last 6 quizzes, prepared by the conventional laboratory instructors, the bias is especially pronounced. The critical ratio test definitely rules out the possibility that the difference between the means of the two groups on the last 6 quizzes may be due to chance.

The inference from this analysis is that the sampling of knowledge by the TV faculty corresponds more uniformly to the content of instruction, regardless of method, than the sampling done by the conventional-laboratory instructors.

Analysis of Student Opinion

The opinions of the students in both groups were surveyed by means of an 18-item questionnaire (see appendix) with a 7-order preference scale for each item. A blank sheet was provided for voluntary comments and appraisal. Some students also took occasion to submit personal appraisals of the television instruction along with their term papers.

Evaluation of answers to opinion questionnaires was done by calculating the scale numbers in which the median scores occurred.

In the appraisal of course organization (Question 2) and teaching effectiveness (Question 13) both the TV and the control groups expressed the same favorable opinion (Median 5 for both groups). The two groups differed, however, in their evaluation of the efficiency of presentation (Question 7) the TV method being judged somewhat superior (TV Median 5, Control Median 4).

In judging the content of the instruction many students in the TV group felt that the physical relationships of the various equipment aspects were not brought out with sufficient clarity (Question 5 - TV Median 4). This is in rather sharp contrast with the control group, where most students felt that the relationships were clear (Control Median 6). On the other hand, the control group was more critical of the nature of the quizzes on course content than was the TV group (Question 3 - TV Median 4, Control Median 3). This opinion is in line with the objective evidence on quizzes, discussed earlier.

In evaluating the relation between the specimen behavior and theoretical formulation, both groups agreed that the relation was easily understood (Question 11 - both Medians 6). This is in spite of the fact that neither group exerted much effort in looking up theoretical references (Question 12 - TV Median 2, Control Median 3).

A point of interest is the extent to which the students considered the course valuable to their profession. Although both groups have generally approved of laboratory courses (Question 15 - both Medians 5), the expression of interest in this particular laboratory was slightly lower (Question 14 - both Medians 4). This may be interpreted in terms of variation of interests among the several major degree groups. Thus, on question 1, regarding usefulness of the course to chosen profession, the median scores of Architects, Electrical Engineers and Management Engineers were 2 and 3. By contrast, the median score of the Aeronautical, Civil, and Mechanical Engineers was 5.

Regarding the students' opinions of their immediate understanding of the material (Question 9) both groups have expressed good understanding (both Medians 5). In the matter of long term retention (Question 10) the TV group expressed less confidence (Median 3) than the control group (Median 4).

An important aspect of TV method of instruction is the physical comfort of the student. This was brought out by answers to Question 8, in which the TV group indicated somewhat more strain (Median 4) than the conventional group (Median 5). Another important consideration pertaining to the physical arrangements is the ease of communication. The answers to Question 6 indicated that the TV group were more reluctant to ask questions (Median 4) than the conventional group (Median 7).

An important change of attitude towards TV as an instructional method was revealed by answers to question 16. While the control group was strongly in favor of conventional laboratory instruction (Median 1), the TV group, whose previous laboratory experience was by conventional instruction, were almost equally divided in their preference for one or the other method. The median value (Median 3) is hardly appropriate in describing the distribution of opinion, since the answers fell in two groups near the extremes of the scale.

Comparison of Costs

The initial investment in equipment for televising was \$12,300 for video equipment; \$700 for sound equipment; \$1000 for lighting; and \$1000 for classroom modifications, a total of \$15,000. Linear depreciation over a 5-year life, in accordance with the recommendations of the General Electric Company, would amount to an annual depreciation cost of \$3000 per year, but the intermittent nature of the equipment use may tend to reduce this. A service contract for maintenance of the equipment costs \$1824 per year.

Although the salary expenses were high during the development process because of the use of two associate professors on the television staff, it was considered desirable in order to develop the instructional procedures to the fullest extent. In subsequent terms each of the professors can serve as a television instructor, with younger staff members serving as program directors and graduate students serving as cameramen. This will help to lower the costs and also provide opportunity for the younger men to understudy the teaching methods of the professors.

Calculations of the direct costs of instruction show that conventional laboratory instruction is the more economical method for course enrollments of less than 350 students and the television instruction is the more economical method for course enrollments of more than 350 students per term. The calculations include the salaries for instructors and professional supervision in conventional instruction, and include staff salaries and television equipment maintenance costs for the television instruction. The results of these calculations are shown in Figure 2, in which the direct instructional cost per student is plotted as a function of the number of students taught by either method in a given term. For course enrollments of 400 and more per term the savings should be sufficient to provide for replacement of the equipment. Additional savings are also present in less maintenance and longer life of the materials laboratory apparatus as the result of its operation by experienced personnel in the television method.

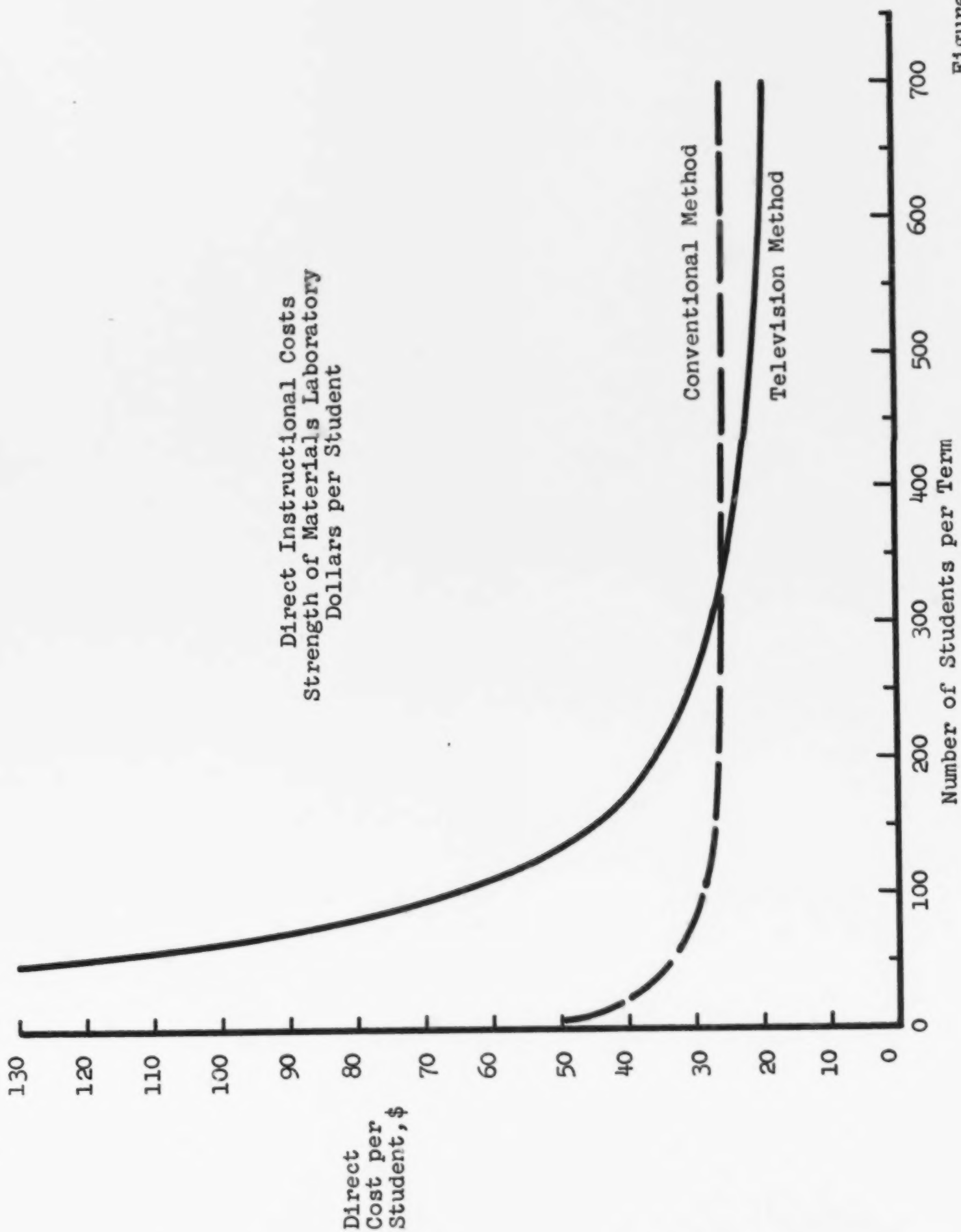


Figure 2

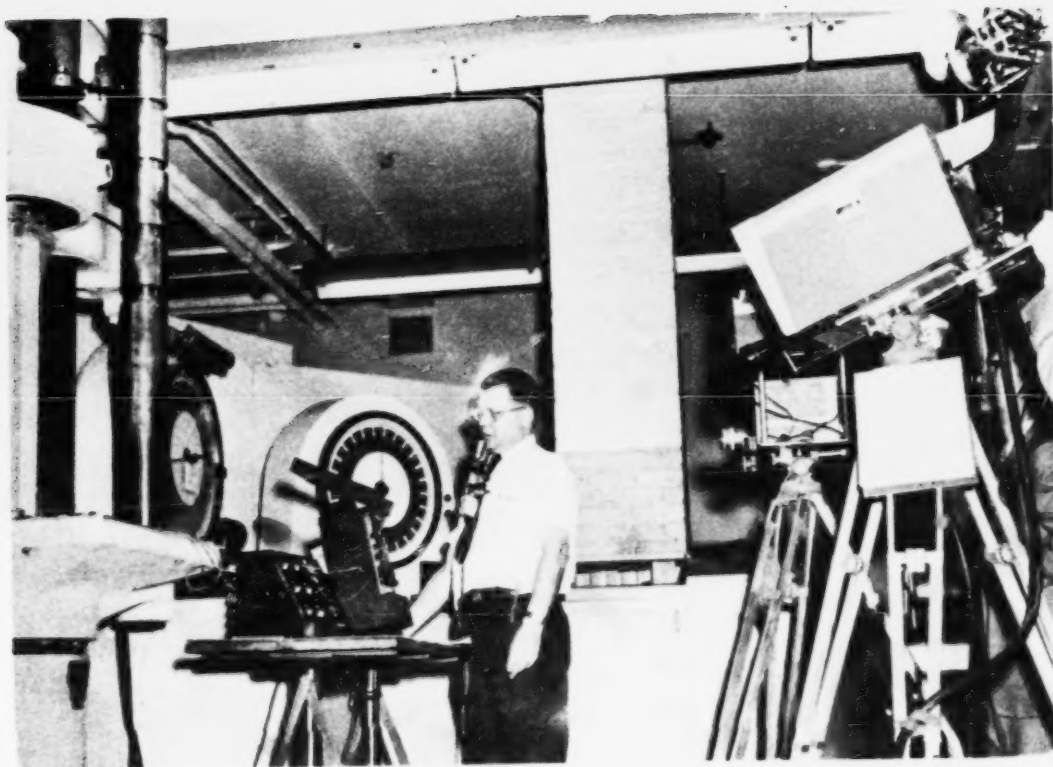
Conclusions

1. Given comparable populations, the television method of instruction described in this report is just as effective in achieving the educational objectives of the course as the conventional laboratory instruction procedure.
2. The effectiveness of both the television and the conventional methods is independent of the student's major degree department.
3. Communication of information by the television method is more uniform from section to section than that provided by instructors in the conventional laboratory classes.
4. With no strong emphasis on machinery under either method of instruction, the conventional instruction develops greater familiarity with the machines than the television instruction.
5. The measuring instruments developed by the television faculty corresponded more closely to the educational objectives of the course than those prepared by the instructors of the control sections.
6. The students' achievement in the course, under either method of instruction, was positively related to, and was slightly higher than, their prior academic standing.
7. The effectiveness of communication, under both methods of instruction, is maximal on the second presentation but tends to decrease with subsequent successive repetitions of the same instructional material.
8. From the student's point of view the television method of presentation of the subject was slightly more efficient than the conventional method. The television group showed, in comparison with the control group, a definite shift of opinion favoring the television instruction.

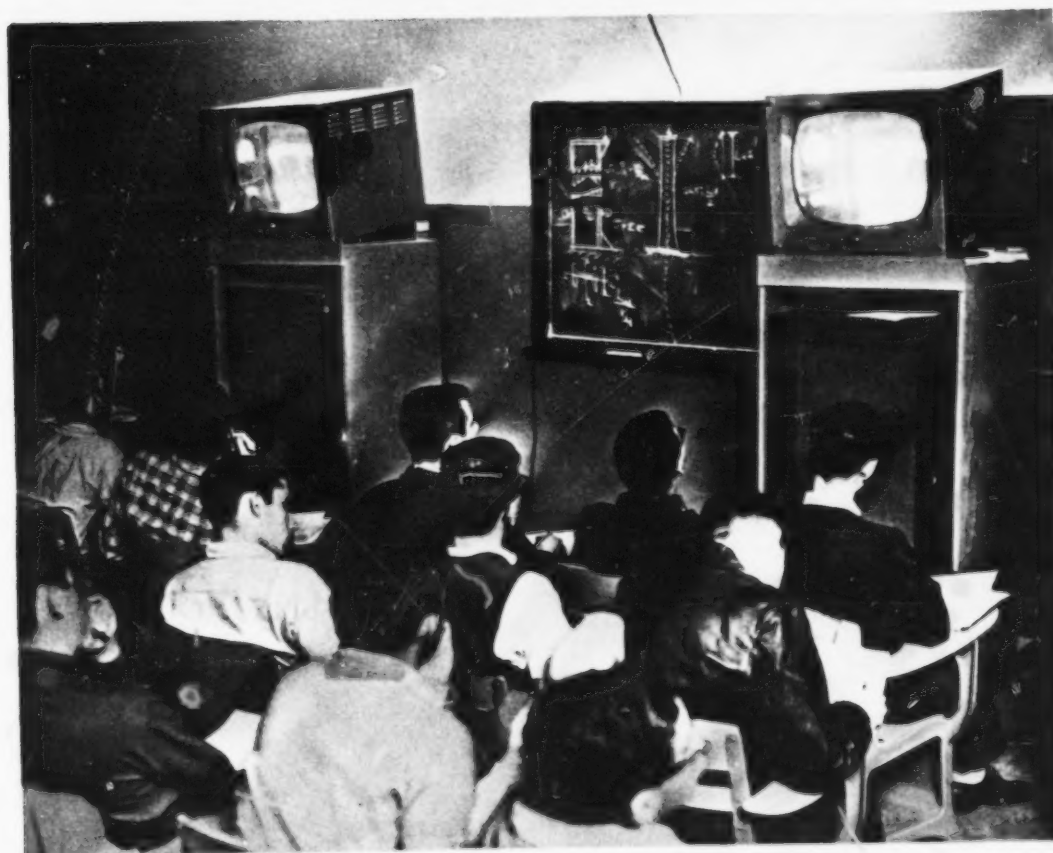
9. The use of the television instruction described in this study can be economically justified for this course only when the number of students to be taught approaches 400 students in each term.
10. The principal value of the television method is that it can make information, which normally would be accessible to few, available to many. This advantage may outweigh the considerations of costs in some educational applications.

Recommendations

1. In anticipation of increased enrollment, provision should be made to equip larger classrooms for television instruction of this course. A definite factor which must be considered in the planning of such classrooms is the physical comfort of the students.
2. In view of the expressed reluctance of the television students to address the teacher by means of a microphone, an effort should be made at the outset to encourage such two-way communication.
3. The capacity of the students may be exploited more fully in the course by making the content more rigorous. This may be achieved readily by a revision of the scripts, and might possibly be enhanced by coordinating the laboratory instruction with the theory instruction during the same term.
4. The number of laboratory sections taught in the course by any one staff member, under either method, should be limited to 3 or 4 per week.
5. The instruments for evaluating student achievement should be prepared under the supervision of senior faculty members, regardless of the method of instruction.



An Experiment Site
Cameras Viewing Strain Indicator and Load Dial



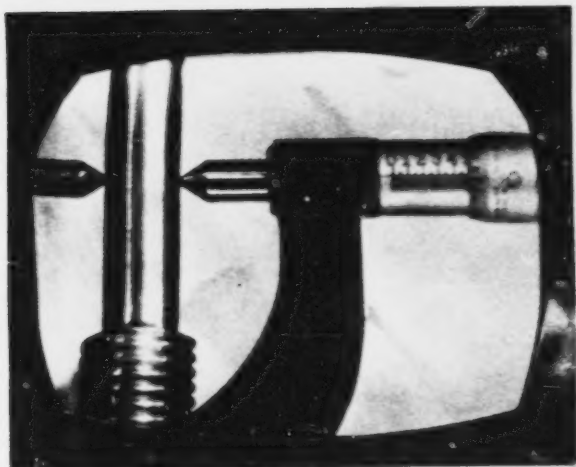
The Television Classroom
Monitors show Split-image of Strain and Load Readings

See Under the Hood

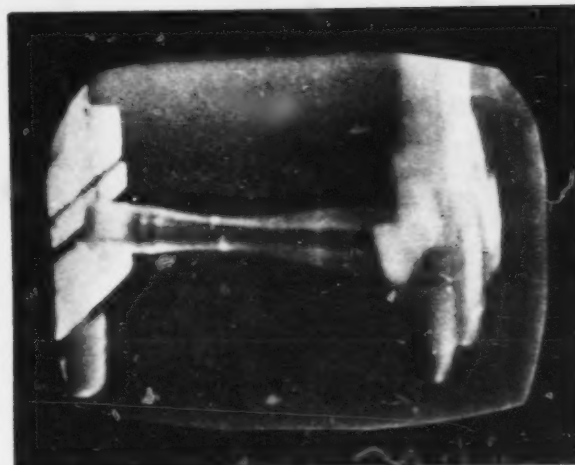
The Control Console

The upper monitor shows the view going to the class. The Program Director selects the view from the two camera monitors. The cameras are directed over the microphone in accordance with the script.

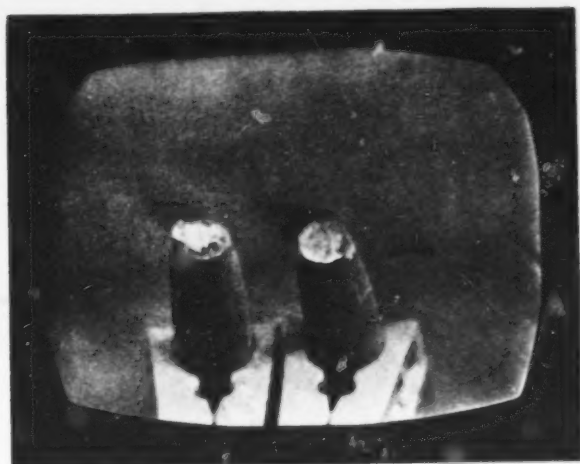
VIEWS FROM CLASSROOM MONITORS



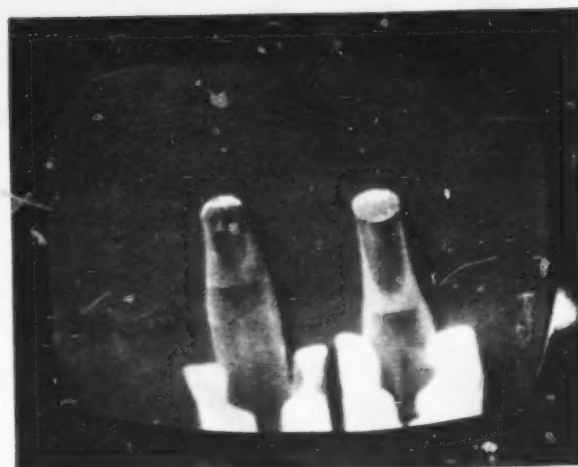
A Micrometer Reading,
Diameter of Tensile Specimen



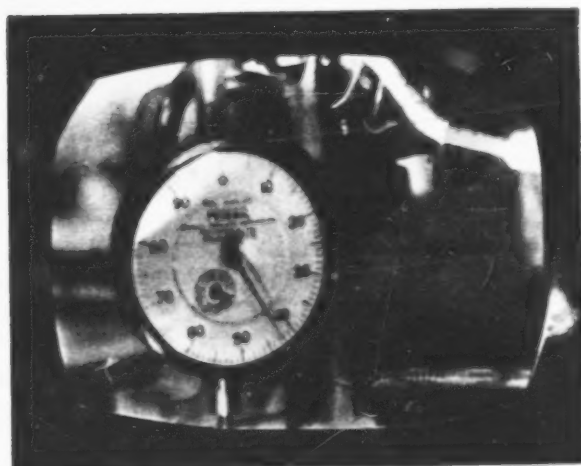
Vibrating Fatigue Specimen,
Fatigue Cracks in Plastic



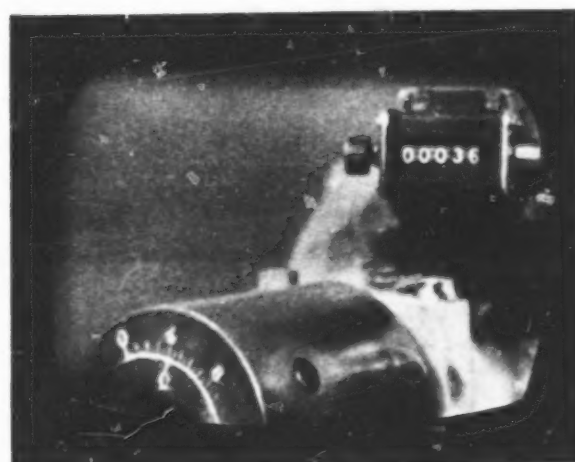
Tensile Fracture Surfaces
Hot Rolled Steel



Fatigue Fracture Surfaces,
Clear Polystyrene Specimen



Dial Indicator Reading,
Deflection, Fatigue Test



Number of Fatigue Cycles,
Eccentric Setting Indicated

APPENDIX I

Television Equipment

Two camera chains of G. E. Monochrome Intra-tel Closed-Circuit Television System with associated controls and video monitors were obtained. One camera was equipped with an electronic viewfinder and a manually operated Zoomar lens. The other was equipped with a manually operated lens turret. A 9-inch portable television receiver was used as a viewfinder for this camera, enabling the viewfinder to be separated from the camera in some situations where space was limited at the experiment site.

The camera controls were mounted in a console on wheels so that the program director could direct the cameras from a location adjacent to each experiment site. Both cameras were operated from the synchronizing generator of one of the control units in order to permit switching operations and the superposition of their video signals for producing split-image views. Both cameras were adapted with lens doublers to produce split-images and with levers to move the vidicon relative to the lens, so that focusing could be done quickly without rotating the lens. A light level of 150 to 200 foot-candles of incident light was found to be sufficient for satisfactory operation.

The following is a list of the items of equipment.

General Electric Video Equipment

- 1 Type TE-3-A Monochrome Camera Chain with Type TV-92-A Electronic Viewfinder and manual 25--75-mm Zoomar lens, tripod and dolly
- 1 Type TE-3-A Monochrome Camera Chain with model 9T001 Portable Receiver; 3 lens turret; 16-mm, 50-mm, 75-mm lenses; tripod and dolly
- 1 Type V-14-A Video Amplifier
- 1 Type PX32-A Video Switcher
- 5 Type CF-21-C Conrac 21-inch monitor
- Cables and connectors

\$12,300

General Electric Audio Equipment

- 2 Model AU 62 Audio Monitor Amplifier
- 2 Model 630 Electrovoice Microphone
- 2 Model FS-2-B Wall Mounted Speaker
- 2 Model FS-1-B Monitor Speaker
- Cables and connectors

700

Lighting Equipment

- Polecats and tubing
- Spotlights and floodlights, 300-watt bulbs
- Cables, sockets, and connectors

1,000

Classroom Equipment

- 50 Tablet-arm student chairs
- 12 Light-proof window shades

Total 1,000
\$15,000

APPENDIX II

38

Questionnaire of Student Opinion

1. How much of the course material do you regard as useful to your profession? In this question consider only the instructor's choice of topics, not his method of presentation.

Hardly any is useful	1	2	3	4	5	6	7	All of it is useful
-------------------------	---	---	---	---	---	---	---	------------------------
2. How well was the material organized? Was each topic covered adequately, or were the time and emphasis distributed unevenly? Consider this question only in reference to the importance of the topics for your profession, not in reference to quizzes.

Extremely unbalanced	1	2	3	4	5	6	7	Perfectly organized
-------------------------	---	---	---	---	---	---	---	------------------------
3. How well did the material covered in the laboratory correspond to the topics covered in quizzes?

Completely unrelated	1	2	3	4	5	6	7	Correspond precisely
-------------------------	---	---	---	---	---	---	---	-------------------------
4. How well did you understand the purpose of laboratory experiments?

Confused on most of them	1	2	3	4	5	6	7	Understood all clearly
-----------------------------	---	---	---	---	---	---	---	---------------------------
5. By watching the experiment how clearly did you perceive the physical relation between controls, dials, and the specimen? Were you confused about these, or was the overall picture clear?

Completely confused	1	2	3	4	5	6	7	Perfectly clear
------------------------	---	---	---	---	---	---	---	--------------------
6. When you did not understand something about the experiment did you feel completely free to ask a question, or did you hesitate?

Hesitated strongly	1	2	3	4	5	6	7	Always felt free
-----------------------	---	---	---	---	---	---	---	---------------------
7. How efficiently was the laboratory time utilized?

A lot of time wasted	1	2	3	4	5	6	7	Every moment utilized
-------------------------	---	---	---	---	---	---	---	--------------------------
8. How much of a strain is the laboratory on your own state of alertness, observation, and intellectual efficiency?

Extremely tiring	1	2	3	4	5	6	7	No strain at all
---------------------	---	---	---	---	---	---	---	---------------------
9. At the end of the experiment, how well could you describe to someone who is not in the course the nature of the experiment?

Could not do it at all	1	2	3	4	5	6	7	Could do it perfectly
---------------------------	---	---	---	---	---	---	---	--------------------------

10. How well, do you think, will you be able to describe it six months from now?

Could not do it at all 1 2 3 4 5 6 7 Could do it perfectly

11. How clearly did the course bring out the relation between physical behavior in the laboratory and previously developed theoretical formulation?

Did not see any relation 1 2 3 4 5 6 7 The relation was obvious

12. How much of an effort did you make on your own to relate practice and theory, by reviewing your previous course in theory and looking up references?

As little as possible 1 2 3 4 5 6 7 Much more than was required

13. What is your opinion of the overall quality of instruction?

Extremely poor 1 2 3 4 5 6 7 Undeniably excellent

14. How strongly are you interested in the course?

Not at all 1 2 3 4 5 6 7 Extremely interested

15. What is your opinion of laboratory courses in general?

Utterly useless 1 2 3 4 5 6 7 Highly valuable

16. If you had your choice, how strong would be your interest for one of the two methods of instruction? Place a check in space 4 only if you are completely indifferent.

Regular laboratory 1 2 3 4 5 6 7 T. V. demonstrations

17. To what extent is your preference motivated by a desire for better grades as contrasted with a desire for better instruction? If both are equally important to you, place a check in space 4.

The only aim is grades 1 2 3 4 5 6 7 Motivated only by wish to learn

18. How helpful to you are the handout sheets? Are they constructed efficiently in the sense of giving you adequate and clear preparation for the laboratory, or are they deficient because of omissions or lack of clarity?

Highly deficient in both respects 1 2 3 4 5 6 7 Very clear and complete

PLEASE PUT ANY ADDITIONAL COMMENTS THAT YOU MAY WISH TO MAKE ON THE BACK OF THIS SHEET. PLEASE DO NOT INDICATE WHO YOU ARE. THANK YOU.

APPENDIX IIIMaterials Laboratory 17.60 Course Content

Wherever possible the experiments are designed to permit the comparison of the experimental results with the students' theoretical solution of the same problem.

AssignmentSubject

1. The Behavior of Materials under Compression Stresses. Includes compression tests of wood, steel, aluminum and plaster of paris and a proving-ring verification of a testing machine.
2. The Behavior of Materials under Tensile Stresses. Includes tensile tests of steel, malleable iron, and cast iron specimens.
3. The Strain Hardening Behavior of Materials. Measurement of increasing hardness with tensile strain in aluminum alloy.
4. The Behavior of Materials under Torsion Stresses. Torsion tests of hot rolled steel and cast iron for strength and ductility.
5. The Behavior of Materials under Bending Stresses. Beam tests of short and long wooden beams.
6. The Behavior of Materials under Column Loading. Column tests of short, medium and long columns of steel and aluminum.
7. The Behavior of Materials under Dynamic Impact Stresses. Stresses and deflections of a beam under impact, and Charpy impact tests of steel, aluminum and brass.

8. The Behavior of Materials under Dynamic Fatigue Stresses. Fatigue tests of polystyrene specimens in bending.
9. The Behavior of Materials under Elastic Uniaxial Stresses. SR-4 strain gage measurements of elastic constants in compression.
10. The Behavior of Materials under Elastic Biaxial Stresses. SR-4 strain rosette measurements of stresses in a torsion member.
11. The Behavior of Materials under Elastic Bending Stresses. SR-4 strain gage and rosette measurements of stresses in an aluminum I-beam and measurement of elastic beam deflections.
12. The Behavior of Materials under Eccentric Compression Loading. SR-4 strain gage measurements of stresses in an eccentrically loaded column.